CHAVOUS

Campus Lighting at

the University of Illinois

Electrical Engineering

B. S.

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CAMPUS LIGHTING AT THE UNIVERSITY OF ILLINOIS

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

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COLLEGE OF ENGINEERING

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1912

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ARTHUR MELTON CHAVOUS

ENTITLED   CAMPUS LIGHTING AT THE UNIVERSITY OF ILLINOIS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF   BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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C O N T E N T S .

INTRODUCTION.

Illumination is rapidly becoming one of the broadest fields for future development in electrical engineering. New types of lamps and new ideas and methods of illumination are being constantly brought forward and while many of them offer but little, if any, improvement over present methods, something better than anything that we now have is sure to be developed.

Even with our best electric lamps only from five percent to seven percent of the energy supplied appears as light radiation. All other electrical machines operate at from eighty five (85%) to ninety eight (98%) efficiency depending on type of machine and purposes for which it was developed. It is the problem of the illuminating engineer to develop an electric lamp that will convert ninety (90) percent or more of the energy supplied into light radiation. This will then lower the amount of power supplied for a given amount of light and thereby reduce the operating costs of the lamp for a given candle-power rating.

There are at present two types of electric lamps in general use: these being the arc light and the incandescent light. In the past the arc lamp has been used chiefly for out-door lighting and the smaller incandescent units for interior lighting but the recent developments in the manufacture of metal filaments lamps with their higher efficiencies has made the incandescent rival, and in some instances replace the arc light for outdoor

lighting.   The metal filament lamp is rapidly replacing the arc
light where a low illumination is desired.   Incandescent lamps
spaced closely give a more uniform illumination and are much more
cheaply operated than an arc lighting system giving the same mini-
mum illumination.   The field of the incandescent lamp is in
private parks, driveways and residence portions of cities where
the operation of arc lamps to give a satisfactory illumination
would be almost prohibitive.

There is another system of outdoor lighting which is
very largely used and that in the gas-mantle arc, which gives a
soft, white light that is not too brilliant for ordinary use.

It is the purpose of this paper to compare three systems
for lighting the University Campus considering the installation
and operating costs.

The three systems are:-

> (1)   Gas-mantle arc system,
>
> (2)   Gasoline-gas lighting system,
>
> (3)   Ornamental Tungsten system,

The territory to be lighted includes that part of the campus ly-
ing between Springfield avenue and the Auditorium and between
Matthews avenue and Wright street.

Owing to the plans proposed for further development
and beautifying of the campus the lamp-posts in each of the sys-
tems are to be of some ornamental design.

Campus Lighting at the
University of Illinois.

The present method of lighting the University Campus
consists of six and six-tenths(6.6) ampere, enclosed alternating
current arcs spaced about four hundred (400) feet apart and at a
height of about twenty (20) feet.   This gives a poor illumination
at the point midway between the lamps even in the open and when
one adds the disadvantage due to light being so high and therefore
much of it cut off by the foliage, it is readily seen that the
arc lamp is a poor lighting unit to use in the present instance.
The high intensity and other natural features, of the arc lamp
prevents its being hung low enough to be below the foliage.   The
lamp needed for the Campus is some form of low intensity light
spaced more closely together than the arcs.   Its low intensity
will allow it to be placed sufficiently near the ground to escape
the foliage, without being objectionable to the eyes.


(1)   Gas Mantle Lighting System.

The first system to be considered is a proposed installa-
tion of gas lamps.   The lamps were to be single, upright mantle
arcs placed at an elevation of about ten (10) feet and at a dis-
tance of about one hundred feet.

The company making the proposal was to take all respon-
sibility for installing, maintaining and operating the system.

It was to be operated on an all night schedule equivelent to the four-thousand (4000) hour schedule.   The lamps spaced as above indicated gave a minimum illumination of nineteen thousandths (.019) of a foot-candle which is very near the desired two hundred-ths (.02) of a foot-candle.

The illunination curve and table showing the illumination on the horizontal plane at various distances from the lamp are shown on Curve Sheet No. 1 and Table No. 1 respectively.

The company agreed to install a minimum of one hundred (100) lamps at a cost to the University of twenty-eight (&28) per lamp per year or a total of twenty-eight hundred(&2800) dollars per year.
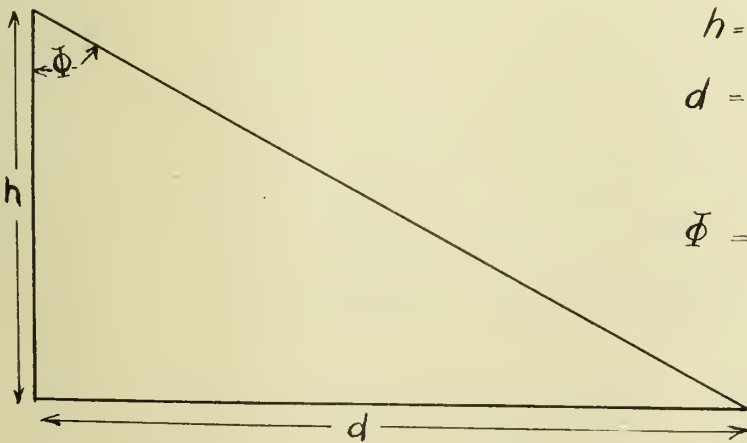
h = height of lamp (feet).

d = distance from base of standard (feet).

$\Phi = tan^{-1} \dfrac{d}{h}$.

To determine the horizontal illumination given by a lamp of in-tensity I at a point (d) from the lamp

$$i = \frac{I \cos^3 \Phi}{h^2}$$

where (i) is the intensity at (d) in foot-candles.   The value of

I being determined from the curve of the lamp at the given angle
Φ .   (See Curve Sheet No. 1)

Table No. 1 shows that at fifty feet from the lamp the illumination
is .0095 foot-candles.   Therefore the illumination at this point
from a similar lamp in the other direction will be .0095 foot-can-
dles and the total illumination at the point will be 2 X .0095 =
.019 foot-candles.   The lamps will then be one hundred (100) feet
apart.

Table No. 1.

d	$\tan\phi$	Φ	I	$\cos\phi$	$\cos^3\phi$	i
0	0	0	0	C	C	0
10	1	45°	66	.707	.373	.2463
20	2	63°26'	94	.4472	.0893	.0838
30	3	71°34'	105	.3162	.0317	.0390
40	4	75°58'	114	.2425	.0143	.0163
50	5	78°41'	119	.1962	.0076	.0095
60	6	80°32'	120	.1645	.0045	.0054

The amount of gas consumed by the mantle used in such
an installation would be approximately four (4) cubic feet per
hour.   The mantle from which the above table was calculated con-
sumed four and six-tenths (4.6) cubic feet per hour.   For one
hundred lamps this would amount to four hundred sixty (460) cubic
feet per hour and for a four thousand hour year, to one million
eight hundred fourty thousand cubic feet.   Taking the rate at
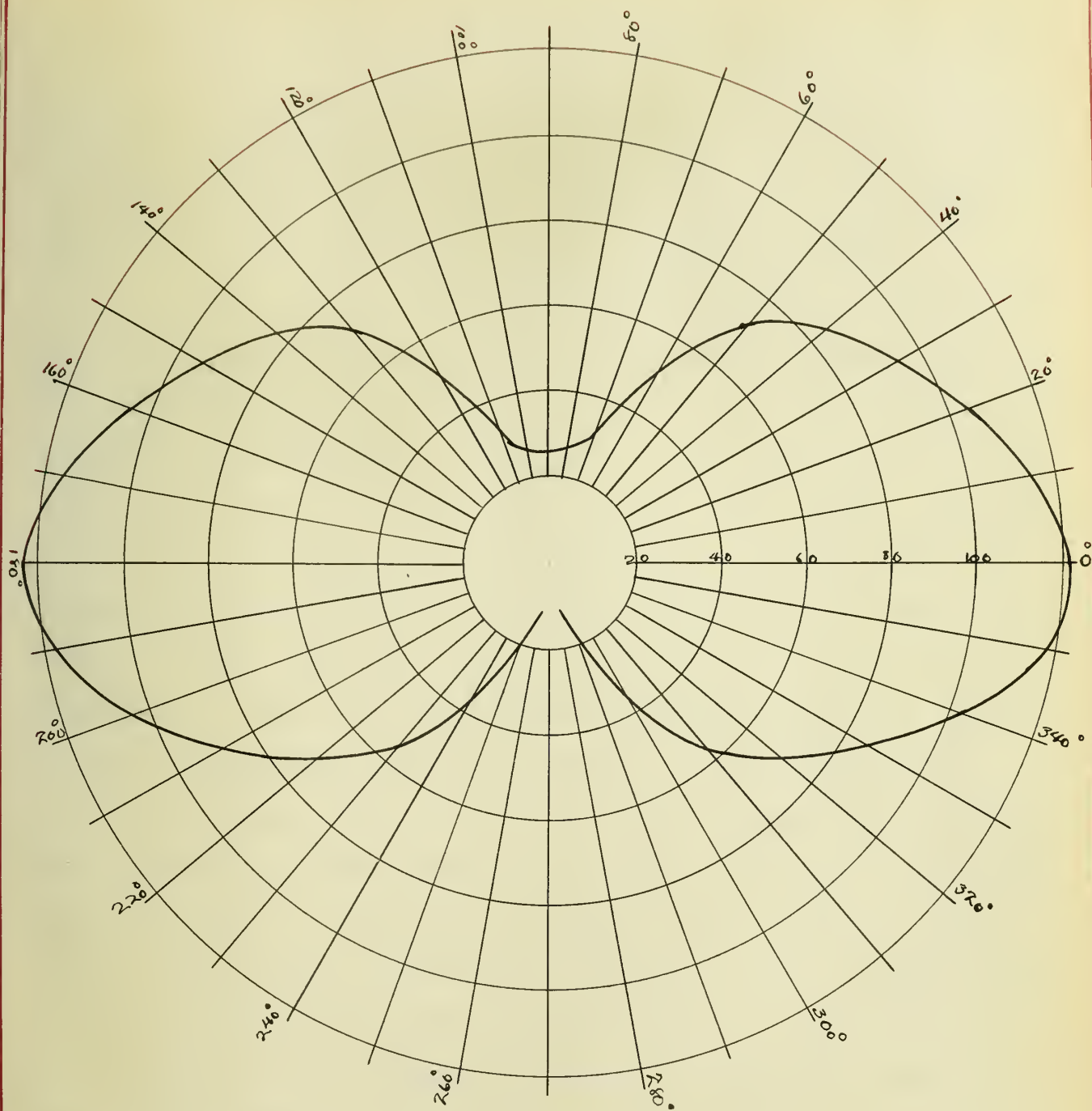
FIG 1.
Illumination Curve for Gas Mantle.
Upright - no reflector.

which gas is now sold to the University namely one dollar twelve and one-half cents ($1.12½) per thousand cubic feet this would amount to two thousand eighty dollars ($2080) per annum.

Owning to the rapid depreciation in the gas mantle, the cost of up-keep on an installation of this kind is rather high. The average life of the ordinary mantle is about five hundred (500) hours and the decrease in efficiency is about one-third of its initial value during the first three hundred (300) hours. Considering the life of the gas mantle as five hundred (500) hours the number of mantles per lamp per year required would be eight (8) or a total of eight hundred (800) mantles per year for the total installation. At twenty (20¢) cents per mantle this would amount to one hundred and sixty ($160) dollars per year for mantles.

Reliable data on the cost of installation such as this was difficult to obtain owning to the great influence which local conditions have on the costs of supplies and materials. Data from a local company however gave the cost of such an installation as about eight (8¢) per foot of pipe laid or on an average of one and one-half ($1.50) dollars per lamp. For an installation of one hundred lamps this would give a total of fifteen hundred ($1500) dollars. This price includes excavations, laying of pipe, erection of standards and mounting of the lamp ready for lighting but does not include cost of anyof the materials. The prices on various designs of lamp post range from about eight ($8) dollars for the cheaper ones to twelve ($12) dollars for the better grade.

Designs similar to those erected on Campus last fall were listed at approximately eleven dollars and fifty cents ($11.50). For the installation of one hundred lamps this will give a cost of one thousand one hundred and fifty ($1150) dollars.

Since the lamp could be tapped into the mains already located in the campus this removes part of the cost of laying the gas mains.

As a summary of the costs of this system, we have:-

Lamp post and fixtures - - - - - - $1150

Installation of lamps - - - - - - 1500

Total - - - - - - - - - - - - $2650

Interest at six (6%) percent and depreciation at ten (10%) gives a total annual expense on investment of four hundred twenty-four ($424) dollars.

Annual expenses

Interest and depreciation - - - - $ 424.00

Renewals of mantles and repairs -   160.00

Lighting, extinguishing and

cleaning at two (2¢) cents

per day - - - - - - - - - -   750.00

Cost of gas consumed - - - - - -   2080.00

Total - - - - - - - - - - - $3414.00

The second proposition under consideration is that of a gasoline-gas lighting system.   The company made two proposals as follows:-

Proposal No. 1. - To install fifty (50) vapor lights, each having a guaranteed rating of two thousand (2000) candle power, each light to be erected upon an ornamental combination concrete and steel standard, not more than eighteen (18) feet high or on suitable ornamental brackets on the sides of the buildings.

The afore said lights to be erected at points on the Campus of the University of Illinois designated by the Supervising Architect and the supporting fixtures to be of designs developed by the Supervising Architect or other persons designated by him.

The entire system or such groups of fixtures as may be decided upon previous to the installation shall all be under the control of a Central Station and shall be automatic in the sense that they may be lighted and extinguished simultaneously from the said Central Station.

By the term install it is understood that the contractor is to furnish all fixtures, equipment, materials and labor. The contractor will maintain the plant for a period of five (5) years and furnish thirty (30) days demonstration service and is bound to enter into a contract for the operation of the plant, for a consideration of not more than two thousand two hundred seventy five ($2275) dollars per annum. All for a consideration of three thousand two hundred forty-six and ninety-three hundredths ($3246.93) dollars.

Proposal No. 2. To install fifty (50) lighting fixtures each bearing a cluster of four (4) two hundred fifty (250) candle-

power vapor lamps, each fixture to consist of an ornamental con-
crete column, not more than twelve (12) feet in height and set
upon a concrete base. The lamps to be supported by curved steel
arms or brackets. The concrete work to be funished in "Blanc"
or "Snow White" Portland cement. The said fixtures to be of a
design developed by the Supervising Architect and to be located
at such points on the Campus of the University of Illinois as may
be directed by him. The entire system or such group of fixtures
as may be decided upon previous to the installation shall be under
the controll of a Central Station. By the term install, it is
understood that the contractor is to furnish all fixtures, equip-
ment, materials and labor.

The contractor will maintain the plant for a period of
five (5) years and furnish thirty (30) days demonstration service
and is bound to enter into a contract for the operation of the
plant for a consideration of not more than two thousand one hundred
fifteen ($2115) dollars per annum.

All for a consideration of three thousand seven hundred
and one-half ($3715.50) dollars.

This type of lamp offers a good lighting unit for areas
where a high intensity of illumination is desired but owing to
its high candle-power it cannot be hung low enough to make it a
practical lamp for this class of service.

On the south campus where there are greater distances
between buildings the lamps are spaced so as to give a minimum
illumination of approximately two-hundredths (.02) foot-candles

but in the northern end of the campus where the buildings are closer together the lamps are necessarily more closely spaced and as a consequence a needlessly high degree of illumination is obtained and such a system could probably replaced by a smaller and cheaper light unit.

The installation costs in both cases includes interest and maintanance charges for five (5) years. Accompanying plan (Fig. A) shows the location and the pipe line connections for the lamps of this system.

The third proposition under consideration is the installation of an ornamental tungsten lighting system. The standards to be of some form of iron or steel standard on the top of which is mounted a single lamp of some suitable size to be later determined. The lamp to be surrounded by large frosted or opal globe. The system of distribution to be used is the series system, designed for use on constant potential circuits. The lamp being connected in series across the high tension mains. The tungsten lamp is particularly adaptable for this class of service due to its low potential and relative high illumination. This lamp is good for outdoor lighting where a low uniform illumination is desired. The tungsten lamp owing to the lower wattage per candle-power which it requires may be profitably used where arc lamps, producing the same minimum illumination , would be prohibitive in operating costs.

The tungsten lamp has several advantages over either of the other systems before mentioned in that it may be connected on

the same circuit with arc lamps such as would be used at the University barns and horticultural buildings at the south end of the campus. As it is proposed to make most of the future development toward the south it would be an advantage to have an installation that would permit of comparatively inexpensive additions.

In the case of the gasolene vapor lighting system it would be necessary to erect a building for the location of the Central Station as there is no room in any of the present buildings. The cost of installation as proposed by the contractor does no take the cost building and value of ground occupied by it into consideration. This would not be required in the tungsten installation since about all the room required by the tungsten system would be that taken up by a control panel and perhaps a transformer.

On pages 15, 16 and 17 are shown the illumination curves for a sixty watt, a one hundred watt, and a two hundred watt tungsten lamp.

Table No. 2.

d	$\tan\phi$	ϕ	$\cos\phi$	$\cos^3\phi$	60 WATT		100 WATT		200 WATT	
					I	i	I	i	I	i
0	0	0	1	1	0	0	0	0	0	0
10	1	45°	.707	.425	35.2	.151	56	.215	112.5	.453
20	2	63°26'	.4472	.089	40.2	.039	62	.055	139	.134
30	3	21°34'	.3163	.031	43	.015	78	.024	146	.045
40	4	75°58'	.2425	.015	44	.008	79	.0119	147	.0207
50	5	78°41'	.1962	.008	44.8	.0074	80	.0064	148	.0113

h = 10 feet

The above table calculated from curves shown on pages 15, 16 and
17.

The method of determining which of the three above lamps
is most economical is as follows:-

Consider the installation of cable the same for each case.
The opal globe reduces the effective illumination about fifteen
(15%) percent (light opal).

In order to obtain minimum illumination of two-hundredths
(.02) foot-candle the sixty watt lamps must be spaced about fifty
(50) to sixty (60) feet apart.   This would require approximately
one hundred sixty (160) lamps.

$$160 \text{ standards @ } \$30 - - - - - - - - \$4800$$

$$\text{Interest and deprecia-}$$

$$\text{tion at } 16\% - - - - - - - - \$ 768$$

Energy consumed

$$160 \times 60 \times 4000 \div 1000 = 38,400 \text{ Kw-Hrs.}$$

$$\text{at } \$.02 \text{ per Kw-Hr} - - - - - \$ 768$$

$$\text{Total annual expense} - \$768 + \$768 = \$1536$$

For the one hundred watt lamp table shows that they should be
spaced about ninety (90) feet apart making an installation of one
hundred lamps necessary

$$100 \text{ standards @ } \$30 - - - - - - - - \$3000$$

$$\text{Interest and deprecia-}$$

$$\text{tion @ } 16\% - - - - - - - - - \$480$$

Energy consumed

$$100 \times 100 \times 4000 \div 1000 = 40,000 \text{ Kw-Hrs.}$$

$$\text{at } \$.02 \text{ per Kw-Hr} - - - - - \$800$$

Total - - - - - - - - - $1280

For the two hundred watt installation the maximum distance between lamps is about one hundred feet giving a total of ninety (90) lamps.

90 standards @ $30 - - - - - - $2700

Interest and deprecia-

tion @ 16% - - - - - - - -- $432

Energy consumed

200 X 90 X 4000 ÷ 1000 = 72,000 Kw-Hrs.

@ $.02 per Kw-Hr - - - - - $1440

Total annually - - - - - - - --$ 1872

The approximate method while it does not include the cost of renewals, repairs and cleaning, indicates that the one hundred watt lamp is the most economical and this unit is used in the remaining calculations and estimates.

The distribution is to be through single duct vitrefied clay or tile conduit. This conduit is about eighteen inches long and three and one-half inches across (inside measurement). The tile are made with male and female ends so that they may be fitted together with cement into watertight conduit.

The lamps are placed about as shown on map (Fig. B). The installation costs are as follows:-

(1) Tile conduit 10,000 ft @ $.08 per ft - - - - - $800.00

(2) Excavation - 18,000 cu. ft. @ $.02 per cu ft - 360.00

(3) Standards(complete) - - 100 @ $30 each - - - - 3000.00

(4)   No. 8 leaded cable - rubber insulated,

single conductor - 10,000 ft @ $.10

per ft. - - - - - - - - - - - - - - - - - 1000.00

(5)   Sundry expenses - (10%) - - - - - - - - - 500.00

Total installation cost   - - - - -$5660.00

This last item includes necessary engineering, removing and clear-
ing away obstacles and returning ground to as near its condition
before installation as possible.

The resistance of No. 8 copper is .6285 ohms per thous-
and feet.   Since the cable is approximately ten thousand feet long
its total resistance is

10,000 X .6285 ÷ 1000 or 6.285 ohms.

The average voltage across the hundred watt tungsten is from
twenty (20) to twenty-five (25) volts and the current varies over
as wide a percent range.   The lamp chosen takes a current of six
and six-tenths (6.6) amperes since it is intended to make it of
such rating that it may be connected in series with six and six-
tenths (6.6) ampere arc lamps.

The loss in the line is then,

$$I^2R = (6.6)^2(6.285) = 273.77 \text{ Watts}$$

273.77 X 4000 ÷ 1000 = 1095 Kw-Hrs per year of

four thousand hours.

Energy consumed by lamps;

100 X 100 X 4000 ÷ 1000 = 40,000 Kw-Hrs.

Total energy is the energy of load plus the line loss or

$$40,000 - 1095 = 41,095 \text{ Kw. Hrs.}$$

at $.02 per Kw. Hr. this amounts to

.02 X 41095 - - - - - - - - - - - - - $821.90

The average life of the tungsten lamp of the size used is about one thousand hours (1000); for a four thousand hour year this requires four (4) lamps per standard per year or a total of four hundred lamps per year.   Total cost of renewals at $1.25 per lamp is:

$$\$1.25 \text{ X } 400 = \$500$$

Investment - - - - - - - - - - - - - -	$5660.00	
Interest on investment @ 6% - -	$339.60	
Depreciation - - - - - @ 10% - -	566.00	
Energy consumed annually- - - - -	821.90	
Renewals - - - - - - - - - - - -	500.00	
Total annual expense - - - - - - - - - -	$2227.50	

or $22.275 per lamp per year.

Summary

No.	Estimates	C*
1	Gas-mantle lamps:- (a) As proposed by company, the company to install, maintain and operate - - - -	$28.00
	(b) As calculated for installation and operation by the University - - - - - -	$34.14
2	Gasolene-Vapor lamp:- (a) Proposal No. 1. Interest on investment @ 6% - - - - - - - $ 194.81 Annual operation cost 2275.00 Total - - - - - $2469.81 Cost per standard - - - - - -	$49.40
	(b) Proposal No. 2. Interest on investment @ 6% - - - - - - - - $ 222.93 Annual operation cost 2115.00 Total - - - - - $2337.93 Cost per standard- - - - - - -	$46.76
3	Tungsten lamps - - - - - - - - - - - - - - -	$22.27

* C is the cost of annual operation per lamp per year.
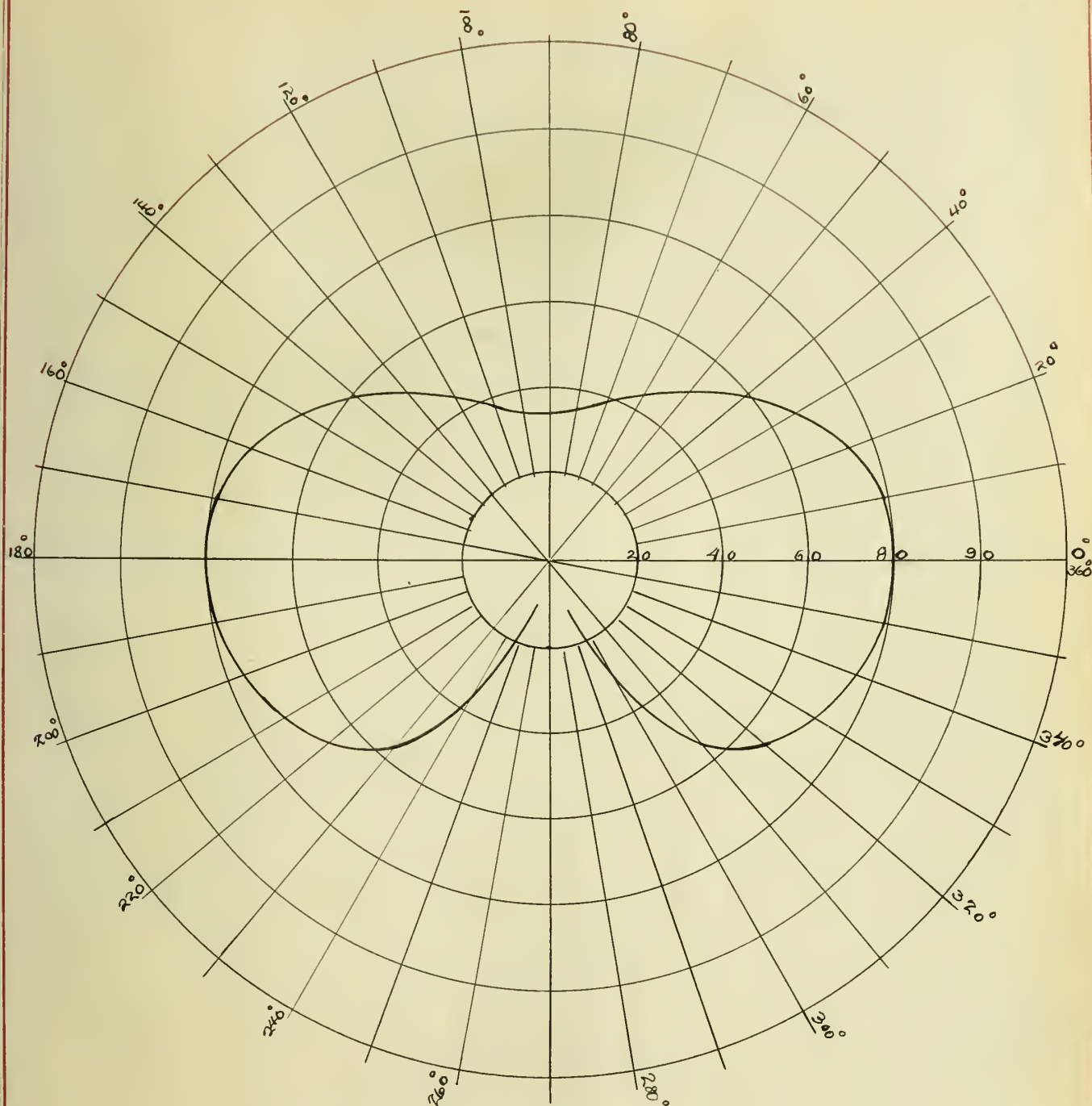
FIG 2.

Illumination Curve for a 100 W Tungsten.
Lamp inverted, no reflector.
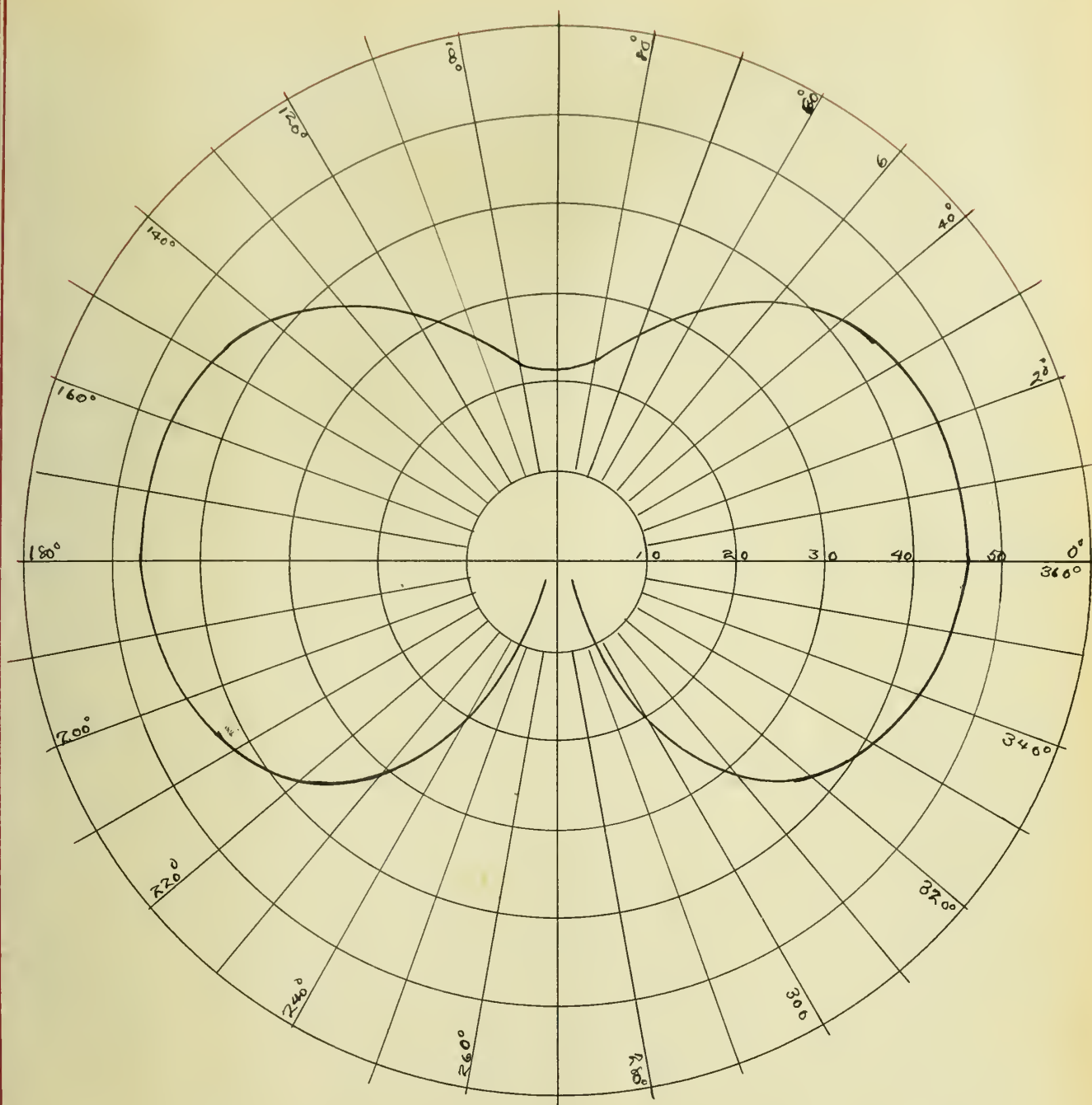
FIG 3.
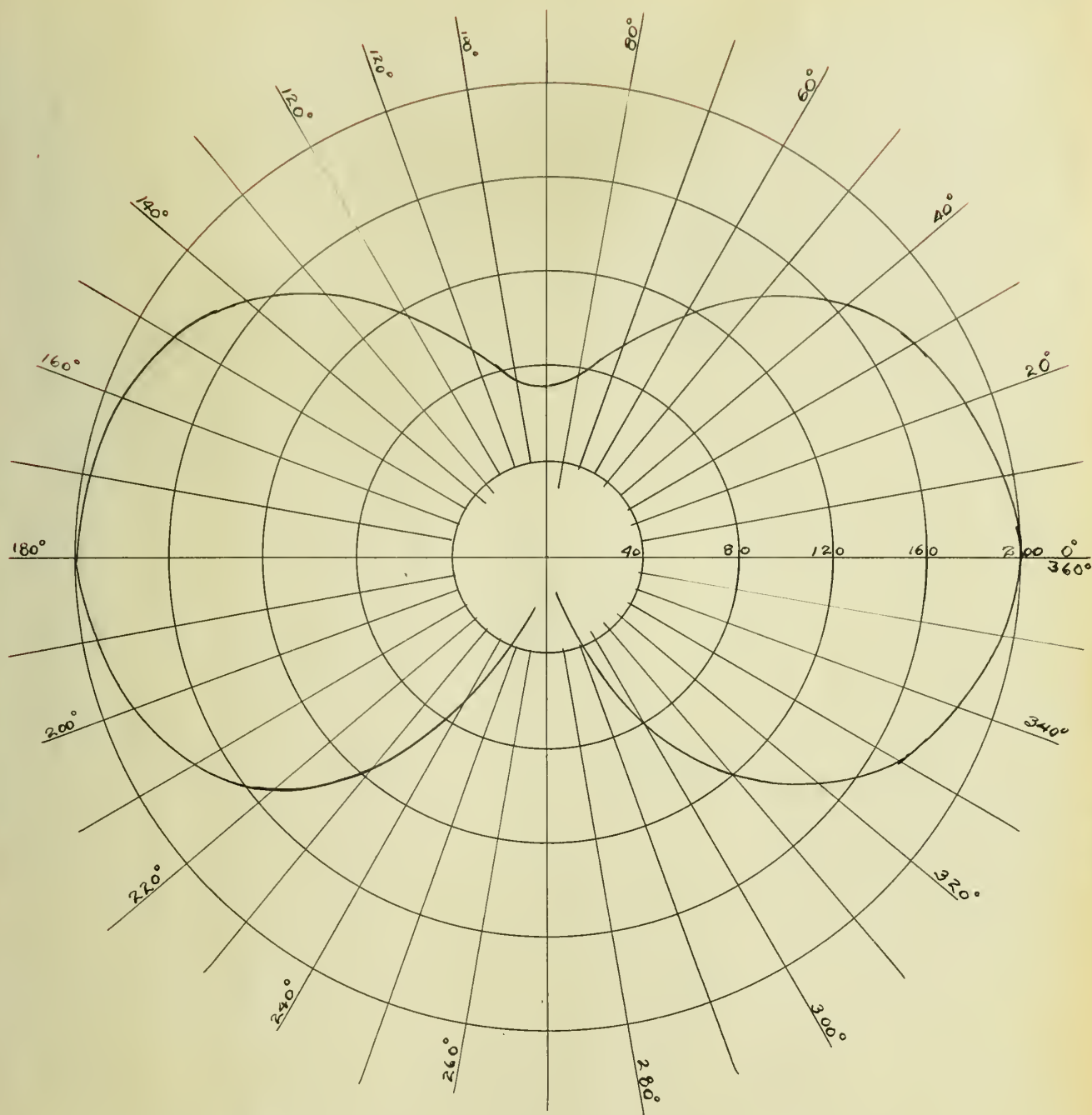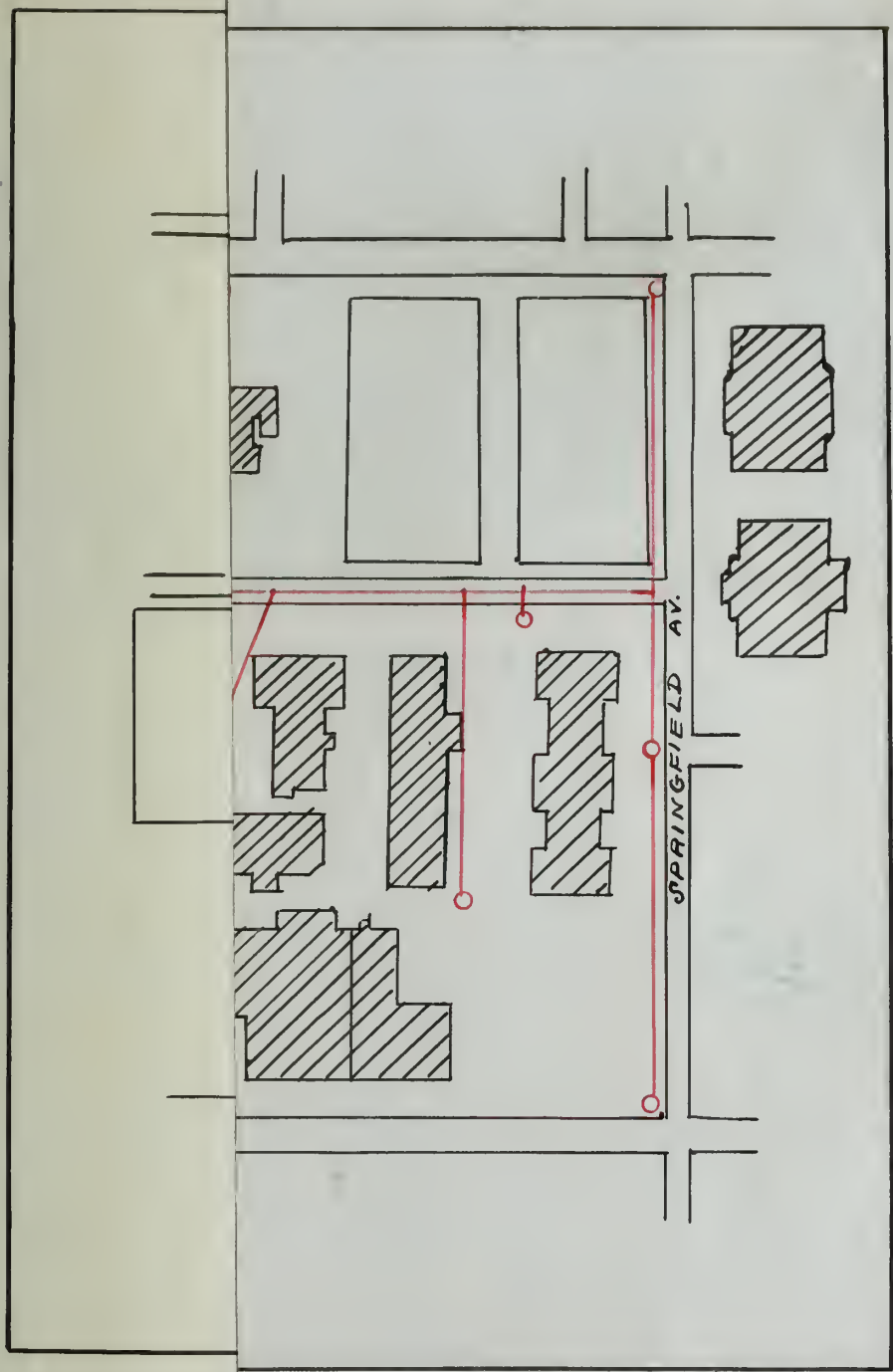Illumination Curve for a .60W Tungsten
Lamp inverted, no reflector.

FIG 4.

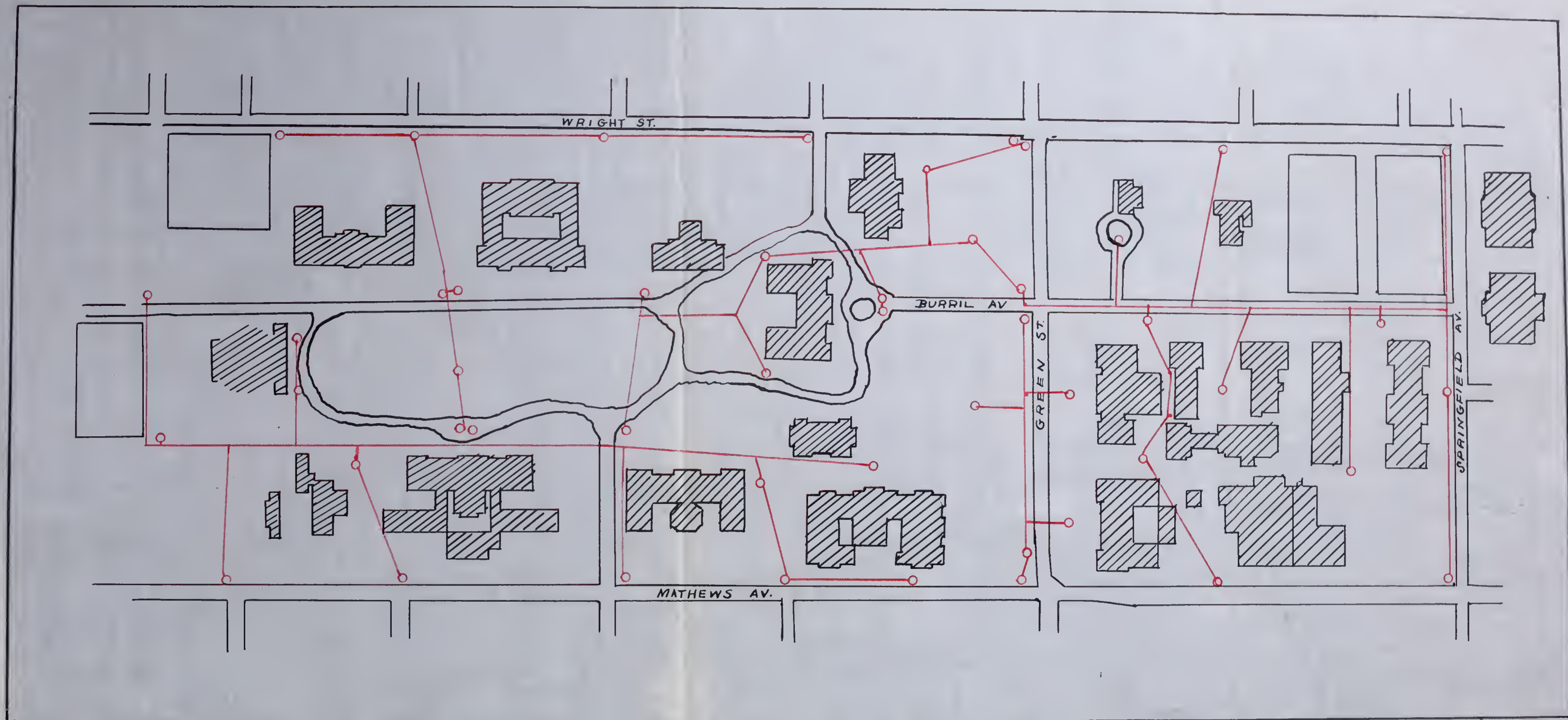Illumination Curve for a 200 W Tungsten.
Lamp inverted, no reflector.

SPRINGFIELD AV.

FIG. A.

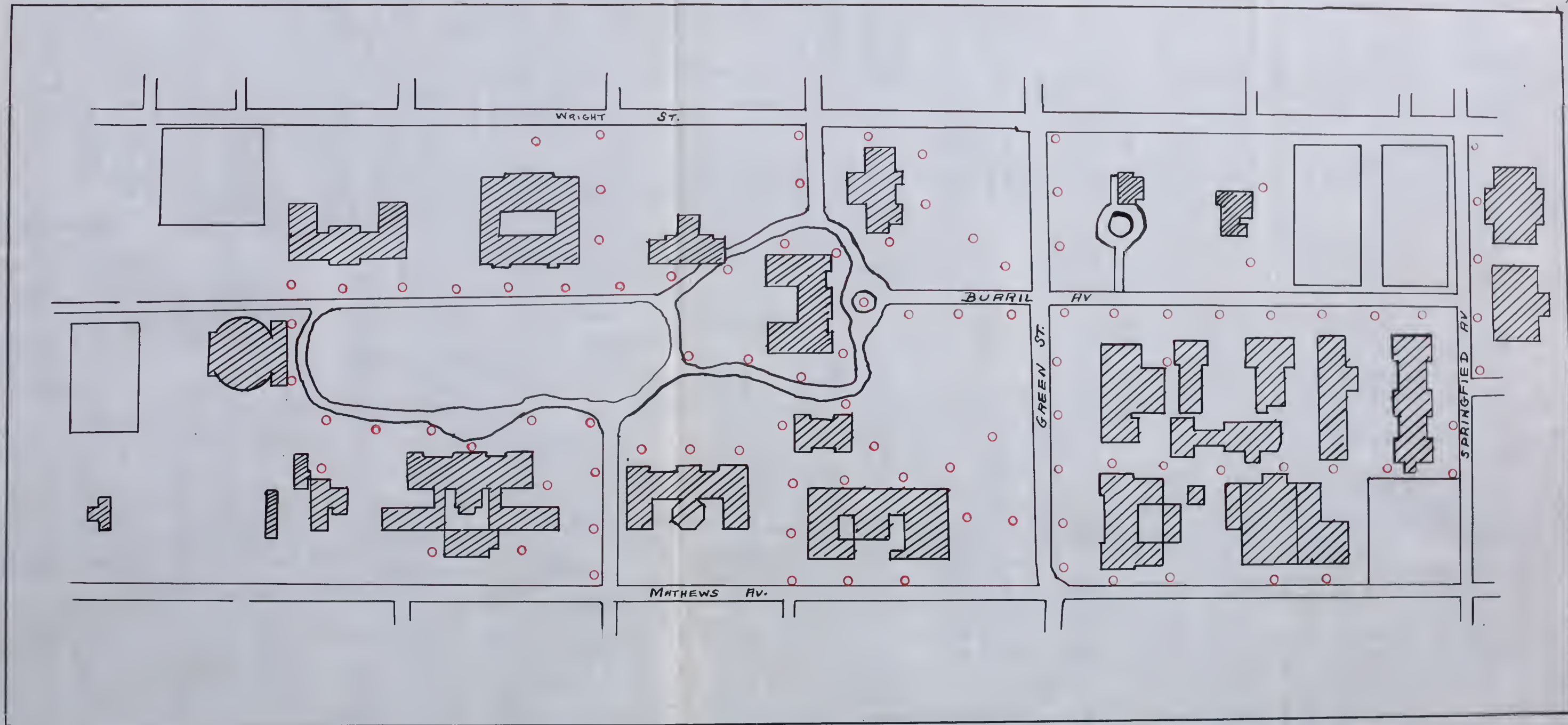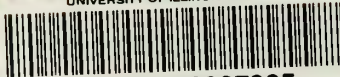Showing position of lamps for Gasolene Vapor system.

FIG. B.
SHOWING POSITION OF LAMPS IN THE TUNGSTEN SYSTEM.